Time Reversal Invariance Violation in Polarized Neutron Beta Decay

L.J. Lising, S.J. Freedman, B.K. Fujikawa, E.G. Wasserman, and the emiT Collaboration†

The existence of CP-symmetry violation in the weak interaction is established in kaon decay, but the implied consequence, time-reversal-symmetry violation, is yet to be observed directly. The emiT collaboration has just completed the first run of an experiment to the search for time-reversal-symmetry violation in free neutron beta decay, using cold, polarized neutrons at the National Institute of Standards and Technology's Cold Neutron Research Facility (CNRF). This experiment, which ran at CNRF during the first half of 1997, utilizes an octagonal array of detectors to observe neutron-decay electron and recoil proton in coincidence. The experiment is designed to detect an angular correlation of the form,

$$\hat{\sigma}_n \cdot (\boldsymbol{p}_e \times \boldsymbol{p}_\nu)$$

which is odd under time reversal. The coefficient of this term in the neutron-decay correlation has been previously shown to be less than 1.1×10^{-3}. The present apparatus is designed for greater sensitivity, and analysis of collected event data is now underway. The neutrons in the cold (T=40 Kelvin) beam are polarized to 96% with a supermirror polarizer. Electrons are detected with four 50 cm long plastic scintillators. The recoil protons, whose maximum energy is only 750 eV, drift in a field free region until they near one of the four proton arrays, where they are accelerated through 36 kilovolts onto thin window PIN diodes. The characteristic delay time between the decay proton and electron is used to distinguish signal from background. The proton drift time is greater than 0.5 μs and most backgrounds are prompt. Figure 1 shows detected proton energy versus time, illustrating the separation of the proton signal from the large prompt background. Anticipated sources of systematic uncertainty were reduced in the detector design and measurements were made to assess the effect of certain crucial factors. As a test of the analysis, one type of spurious T-violating signal was temporarily created by tilting the polarization guide field to be perpendicular to the beam and blocking off half of the beam to destroy its cylindrical symmetry. The presence of the large parity-violating asymmetries (characterized by the A and B coefficient), makes a spin-dependent count rate in the coincidence detector pairs, which mimics the D-coefficient. We were able to see a positive effect at the level of 5×10^{-2}. In the normal configuration the contribution from this effect is below our sensitivity.

Footnotes and References

†The emiT collaboration institutions are: Lawrence Berkeley National Laboratory, University of California at Berkeley, University of Michigan, National Institute of Standards and Technology, Notre Dame University, Los Alamos National Laboratory, and University of Washington.

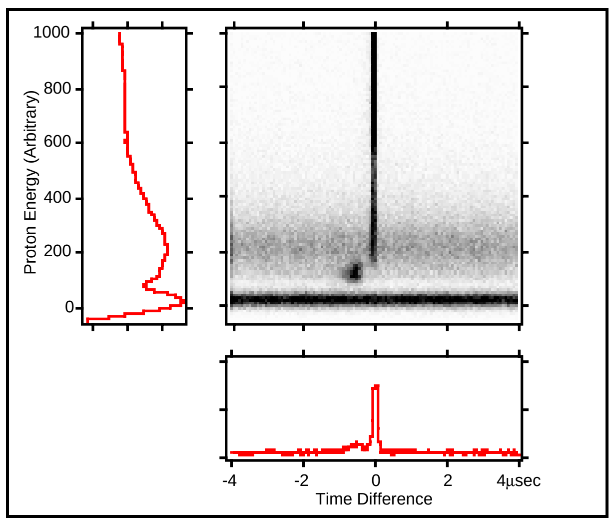

Fig. 1. A plot of proton detector energy versus coincidence time shows clearly the large prompt events, mostly from background gamma rays. Delayed proton coincidences show up to the left of the prompt events in this figure. The enhancement at 0.5 microseconds delay is from neutron decay.